SPECIAL REPORT 99-4

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Frost Inhibition on Turfgrass

Antonio J. Palazzo, Timothy J. Cary, Susan E. Hardy, and Joyce A. Nagle

April 1999

Abstract: Frost is a common problem for golf courses in the early morning hours in the spring and fall. Walking on frosted turf turns it a dark bluish color initially and kills the leaf tissue, eventually causing an unsightly appearance. The objective of this study was to conduct a series of experiments to evaluate the effectiveness of a recently introduced frost-inhibition product called Frost-B-Gone (FBG) in preventing the formation of frost and subsequent damage to turfgrass. The material was studied at concentrations of 0, 5, 10, 15, and 20% and applied at a rate of 1629 L ha^{-1} (174 gal. $acre^{-1}$). The results of these experiments showed that the FBG compound was effective in preventing frost on a bentgrass turf used for greens. Application of FBG at concentrations of 10, 15, and 20% six hours before frosting conditions was consistently effective in reducing the occurrence of frost on bentgrass leaf surfaces. FBG also had a residual frost-inhibition effect when the sod was frosted a second time without re-treatment. The frost-producing technique developed in these experiments proved successful with herbaceous plants and may be used to prepare plants for cold-tolerance or satellite-identification studies.

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Prepared for
OFFICE OF THE CHIEF OF ENGINEERS

PREFACE

This report was prepared by Antonio J. Palazzo, Research Agronomist, Geochemical Sciences Division (GCD), U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire; Timothy J. Cary, Physical Science Technician, GCD, CRREL; Susan E. Hardy, Research Program Specialist, GCD, CRREL; and Dr. Joyce A. Nagle, Manager, Office of Research and Technology Applications, CRREL.

The authors acknowledge the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC), BT25 Environmental Quality Research Program, and the Frost-B-Gone Company for funding, and the Cooperative Research and Development Agreements (CRADA) program that made this evaluation possible. They also thank Joseph Hanafin and Joseph Savignano, Frost-B-Gone Company, for their technical advice on the FBG product; William Putnam, formerly of the Frost-B-Gone Company, for his general support and interest; Robert Sanborn of the Hanover Country Club for supplying the sod; Steven Pugh, CRREL, for setting up the frost plates in the Frost Effects Research Facility (FERF); and Dr. Giles Marion and Dr. Charles Ryerson, CRREL, for technically reviewing the manuscript.

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Frost Inhibition on Turfgrass

ANTONIO J. PALAZZO, TIMOTHY J. CARY, SUSAN E. HARDY, AND JOYCE A. NAGLE

INTRODUCTION

Frost is a common problem for golf courses in the early morning hours in the spring and fall. When frost occurs, course managers may close play to prevent injury to the turf. Walking on frosted turf turns it a dark bluish color initially and kills the leaf tissue, eventually causing an unsightly appearance. The daily delay in opening courses until the frost has melted reduces income and causes ill will among the golfers.

Frost is caused by water vapor depositing as ice crystals on plant leaf tissue. When air cools, its ability to hold water vapor decreases until the air is saturated at the dew point or frost point. When objects, such as grass leaves, cool independently of the air to either the dew point or the frost point, water droplets or ice crystals grow on the cooled leaves even if the air itself is not saturated. Dew forms at temperatures above freezing, and frozen dew occurs when the condensed droplets cool below 0°C (32°F). Frost forms when saturation occurs below freezing and water vapor deposits directly as ice crystals on the cold leaves at the frost-point temperature without an intervening liquid stage. Cooling of grass leaves to saturation is enhanced on clear nights, which encourage deeper radiant cooling, and is diminished on cloudy nights because clouds are typically warmer than the clear sky (Beard 1973).

During frost, icing occurs inside the leaf blade or on the leaf surface or both. Pressure on the rigid frozen tissues caused by human or vehicular traffic disrupts the brittle protoplasm—the cellular structure inside the leaf. This leaf injury does not cause permanent injury to the turf because the turfgrass crowns readily produce new leaves. The leaf damage can be avoided either by withholding or diverting traffic from the turfgrass areas during periods when the leaf tissue is frozen or by a light application of water (called syringing) in the early morning to thaw the frozen turfgrass tissues (Bruneau et al. 1992).

OBJECTIVE

The objective of this study was to evaluate the effectiveness of a recently introduced frost-inhibition product called FROST-B-GONE (FBG) in preventing the formation of frost and subsequent damage on turfgrass. The material was studied at concentrations of 0, 5, 10, 15, and 20% and applied at a rate of 1629 L ha^{-1} (174 gal. acre^{-1}). This was a cooperative effort between the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the FROST-B-GONE Company.

This study was also an excellent opportunity for CRREL to develop processes to artificially produce frost on plants. The methods used here may prove useful in testing the frost tolerance of plants being developed under several of CRREL's land rehabilitation research work units. New plant cultivars that are more frost tolerant will be more adaptable to the military's training mission in cold regions. The frost-producing techniques will also be useful in studies on real-time site characteristics. Remote-sensing signatures of frosted plants may be correlated to early morning air-soil temperatures in future studies.

MATERIALS AND METHODS

Frost production

CRREL has circulated ethylene glycol within metal plates to freeze soils and pavements (Eaton 1988, 1989), but we found nothing in the literature about producing artificial frost on turfgrasses. The temperature of the ethylene glycol can be adjusted to uniformly reduce ambient temperatures enough to produce frost on objects near the plates in a closed environment. Based on studies on formation of frost in nature, the two major variables for producing frost on plants would be the distance of the plants to the frost plate and the temperature of the plates (Ryerson and Claffey 1994). We found that it is possible to produce frost when the plate temperature is set at –2°C (23°F) and the plates were placed 30 cm (12 in.) above the plants. This combination created an air temperature of –2°C (28°F) at the surface of the sod and took approximately 30 minutes to produce frost on the plants after the desired temperature was attained.

Frost prevention

We conducted a series of experiments in fall 1996 and spring 1997 to determine the prevention of frost on a mature creeping bentgrass sod (*Agrostis palustris* Huds.) treated with the FBG frost inhibitor. The sod for each season's experiments was cut with a sod cutter into 2-cm- (0.8-in.-) thick sections of 0.3 m by 1 m (1 ft by 3.3 ft) from a practice green at the Hanover Country Club in Hanover, New Hampshire. The sod was placed on a sand bed adjacent to the CRREL greenhouse in Hanover, New Hampshire. On the first and third day prior to each experiment, the turfgrass sod was irrigated with 1 cm (0.4 in.) of water. The second day, the sod was fertilized with a complete nutrient solution.

On the fourth day, the sod was sprayed with treatments consisting of FBG solutions of 0 to 20% in water at an application rate of 1629 L ha^{-1} (174 gal. $acre^{-1}$). The FBG solutions used in the first two frostings in 1996 included a gel agent to thicken the solution and prevent its running off the leaf surface. The gel agent was a powdered additive dispersed in the water-FBG solution at a concentration of approximately 0.25% by weight. The gel that formed on stirring was clear, thick, and highly viscous; it could be applied to the turfgrass with conventional spray equipment, leaving a coating on the leaf that would not run off the leaf surface even after several hours. Subsequent trials were run without the gel agent. All applications were made to completely cover the leaf surfaces, and there were either two or three replications of each treatment. Each replication for a single treatment used a full sod section.

Six hours after treatment with FBG, the sod pieces were transferred to the Frost Effects Research Facility (FERF) at CRREL and placed below a metal plate that circulated ethylene glycol (Fig. 1) to produce frost as described above. After the frost plates reached the desired temperature, the surface of the sod was kept at –2°C (28°F) for three hours. Temperatures at the surface of the sod pieces were measured with unshielded thermocouples and recorded every 10 minutes with a Model EL 824-GP data logger (Omni Data International, Logan, Utah). The sod was then placed back on the sand bed, and a 79-cm^2 wooden block (Fig. 2) was placed on the turf surface, stepped on to compress the turf, and removed. Three hours after compression with the wooden block, the sod was irrigated with 1.25 cm (0.5 in.) of water to prevent drying.

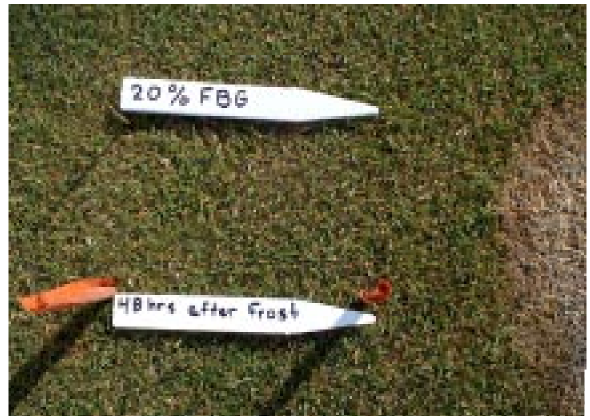
Leaf color within the area compressed by the wooden block was recorded and photographed after 48 hours (Fig. 3).

In two series of tests, the same sod pieces were frosted twice and FBG was applied before each

Figure 1. FERF frosting apparatus. Untreated, frosted turf is in the foreground and FROST-B-GONE-treated turf is in the background.

Figure 2. Wooden block used to compress turf to cause injury after frosting.

a. 0% Frost-B-Gone application.



b. 20% Frost-B-Gone application.

Figure 3. Leaf color variations in the treated-vs.-untreated area were recorded 48 hours after frost.

frosting; the FBG contained the gel agent only in the first series of two frostings. Two subsequent tests on separate sod pieces consisted of a single application (without gel) and frosting. A final series consisting of one application (without gel) and two frosting cycles (the sod was irrigated but not re-treated with FBG before the second frosting) was conducted to test the residual effects of FBG on frost prevention. The details of each study are included in the "Results" section.

RESULTS

In all studies, frost was observed on the leaf surfaces of the control plants (0% FBG treatment). Similarly, leaf damage—browning of leaves—occurred in the compressed area for all control treatments (0% FBG). The details of experimental design and leaf injury in the compressed areas for each frosting date are shown in Table 1.

Table 1. Frosting studies on bentgrass turf.

Date of frosting and damage	*Objective*	*Methods*	*Results*
4 September 1996	Test FBG with gel for (1) frost prevention and (2) turf damage.	Four rates (0, 10, 15, 20%) of FBG with gel with two replications of each.	Good frost control on all FBG-treated plots and no initial signs of damage from the FBG treatments.
6 September 1996	Test reapplication of FBG with gel.	Repeat of 4 September 1996 on same sod pieces.	Good frost control on all FBG-treated plots. After 48 hours, leaf damage (browning out) appeared on sod receiving 20% treatment.
22 October 1996	Test FBG (no gel) for (1) frost prevention and (2) turf damage.	Five rates (0, 5, 10, 15, 20%) of FBG (no gel) with two replications of each.	Good frost control on all treated plots except the 5% treatment. No signs of damage after 48 hours.
25 October 1996	Test reapplication without gel.	Repeat of 22 October on same sod pieces.	Same as 22 October.
25 August 1997	Test FBG (no gel) for (1) frost prevention and (2) turf damage.	Four rates (0, 10, 15, 20%) of FBG (no gel) with three replications of each.	Good frost control on all FBG-treated plots. No damage after 48 hours.
7 September 1997	Test FBG (no gel) for (1) frost prevention and (2) turf damage.	Four rates (0, 10, 15, 20%) of FBG (no gel) with three replications of each.	Good frost control on all FBG-treated plots. Some tip burn on 20% (see Summary). No burn after 48 hours of watering.
16 September 1997	Test FBG (no gel) over two days with no reapplication.	Four rates (0, 10, 15, 20%) of FBG (no gel) with three replications of each.	Good frost control on FBG-treated plots.
17 September 1997		Same sod irrigated with 1 cm (0.8 in.) of water but not re-treated.	10% FBG treatment showed patchy frosting, but no damage was observed.

SUMMARY

The series of experiments showed that the FBG compound was effective in preventing frost on a bentgrass turf used for greens. Frost was inhibited under the following conditions of this study:

- Application of FBG at concentrations of 10, 15, and 20% at a rate of 1629 L ha^{-1} (174 gal. $acre^{-1}$) six hours before frosting was consistently effective in reducing the occurrence of frost on creeping bentgrass leaf surfaces.
- The gel ingredient appeared to cause some leaf injury to the turf at the 20% FBG treatment. At the time the symptoms were observed, the reason for this injury was not clear. The quantity of gel agent applied was consistent across all FBG treatments, except the control; therefore, we should have observed the injury in all the FBG treatments. In subsequent conversations, the FBG Company* stated that they had not noted this effect at customer sites or in related studies at Clemson or Iowa State Universities. Therefore, we are not sure what caused the leaf injury. This was one of our first experiments with this product and the material may have been contaminated or misapplied.
- In the 16–17 September 1997 series, there was a residual frost-inhibition effect of FBG when the sod was frosted a second time without reapplication. In the 17 September study, the sod was irrigated with 1 cm of water between frostings and the results showed patchy frosting on leaf surfaces in the 10% FBG treatment when the sod was refrosted; no frosting was observed in either the 15 or 20% treatments. The patchy frosting on the 10% treatment could be related to the low concentration of the chemical applied and the dilution due to the irrigation. The patchy frosting is probably not related to incomplete coverage of the chemical because the same liquid volume was applied to all treatments and there were no problems with solubility of the chemical during mixing with water.
- In the 7 September 1997 experiment, we attributed the patchy tip burn on the sod treated with 20% FBG to purple leafspot disease and not to the FBG product.
- The technique developed in this study proved to be a successful method for producing frost on herbaceous plants. This method may be used in future studies on plant characteristics and on plant tolerance to cold temperatures.

* Personal communication, Joseph Hanafin, FROST-B-GONE Company, Myrtle Beach, South Carolina, 1998.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1999	

4. TITLE AND SUBTITLE

Frost Inhibition on Turfgrass

5. FUNDING NUMBERS

6. AUTHORS

Antonio J. Palazzo, Timothy J. Cary, Susan E. Hardy, and Joyce A. Nagle

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, New Hampshire 03755-1290

8. PERFORMING ORGANIZATION REPORT NUMBER

Special Report 99-4

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of the Chief of Engineers
Washington, D.C. 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES For conversion of SI units to non-SI units of measurement consult *Standard Practice for Use of the International System of Units (SI),* ASTM Standard E380-93, published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pa. 19428-2959.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

Available from NTIS, Springfield, Virginia 22161.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

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14. SUBJECT TERMS

Frost damage Frost inhibition Frost injury Turfgrass

15. NUMBER OF PAGES
7

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102